THE NICKEL BULLETIN

A SUMMARY OF CURRENT INFORMATION ON NICKEL

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STANDARD SPECIFICATIONS COVERING CHROMIUM-NICKEL CORROSION- AND HEAT-RESISTING STEELS *pages* 104-105

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ABSTRACTS OF CURRENT PUBLISHED INFORMATION ON NICKEL AND ITS ALLOYS

GENERAL

Methods for Rapid Identification of Metals: A.S.T.M. Symposium

AMER. SOC. TESTING MATERIALS: 'Symposium on Rapid Methods for the Identification of Metals.' *A.S.T.M. Special Tech. Publn.* 98, published 1950, containing papers and discussion presented at the Annual Meeting of the Society, June, 1949.

The nature of the material contained in the majority of the papers is of a reference type, which must be consulted in the original. The scope of the information obtainable from them is briefly indicated below.

F. FEIGL: 'Development, Present State and Outlook of Spot Test Analysis,' pp. 1-11.

A historical review and appraisal of the present position, based on the author's own unique experience and knowledge, and on the literature, to which reference is made in a *bibliography* of 37 references.

H. W. HERMANCE and H. V. WADLOW: 'Electro Spot Testing and Electrography,' pp. 12-34.

The basic principles of electrographic analysis, the nature of the apparatus used, and the technique of operation are described, with good diagrams, and recommendations are made with regard to choice of equipment, and of transfer medium, preparation of specimens, transfer operations, etc. Some general observations are made on reactions and sequences of treatment which can be used to identify transferred products, and the application of spot testing is demonstrated by tabular schedules showing the various stages in procedure for systematic examination of a pure metal, and of copper and copper alloys. Some general principles governing conditions for electrographic pattern reproduction are reviewed.

R. R. WEBSTER: 'Instruments for Rapid Metal Identification,' pp. 35-48.

The rapid development in this field during the past few years is noted, with particular emphasis on the important contribution made by recent advances in electronics and related fields of instrumentation. Rapid testing methods now available are discussed under the classification of techniques which distinguish materials (1) by the quality of the sparks emitted during grinding, (2) by radiation from an electric arc or spark emitted when the material to be tested is used as one of the electrodes, (3) by hardness, (4) by frictional electricity or tribo-electric effects, (5) by thermoelectric effects, (6) by magnetic characteristics, and (7) by electrical properties. Apparatus used in the various tests is described, and the nature of the information obtainable by the respective methods is considered. The extent to which the data so obtained can be used for identification is critically assessed.

H. KIRTCHIK: 'Separating Alloys by Relative Spot Tests,' pp. 49-53.

This paper describes a 'relative sorting technique' which has been developed at the works of General Electric Company of America, for very rapid sorting of mixed materials. Its value is demonstrated by description of sorting tests for differentiation of (1) Inconel and Nichrome; (2) S-495, Hastelloy B and 17W; (3) Hastelloy B, Timken 16-25-6 and S-816; (4) 17W and 18-8 steels containing molybdenum, titanium or niobium, and (5) S-495 and a range of cobalt-base alloys. In some cases a more specific spot test procedure is adopted as supplementary to the methods described.

R. P. NEVERS: 'Rapid Methods for the Identification of Copper-base Alloys,' pp. 54-7.

Schedules show the steps involved in rapid identification of (1) brass, and (2) bronze alloys. In the case of the brasses the instructions include technique for distinguishing between nickel silver and cupro-nickel.

A. LEWIS and D. R. EVANS: 'Rapid Identification of Metal Finishes,' pp. 58-60.

This note describes a rapid identification kit developed during the war by Western Electric Company, and now commercially available. The sequence of analysis for which it can be used is detailed, indicating its capacity for detection of cadmium, nickel, silver, tin, lead, chromium and zinc coatings.

N. GALITZINE and S. E. Q. ASHLEY: 'Examination of Plated and Protective Coatings by Electrographic Analysis,' pp. 61-8.

Following the paper by Hermance and Wadlow, which described the principles of electrographic analysis (*vide supra*), this paper deals specifically with the application of electrographic analysis to the study of plated or coated surfaces, and particularly with the examination of such surfaces for discontinuity of coating or the presence of holes. Nickel plating is among the forms of metallic coating discussed.

H. B. LEA: 'A Field Test Kit and Procedure for Use in the Rapid Identification of Some Nickel Alloys and Stainless Steels,' pp. 69-72; disc., p. 72.

A description is given of a test developed by Eastman Kodak Company for separation and identification of the following materials: nickel, Monel, Inconel, chromium-nickel stainless of the 18-8-Mo grade and, *as classes*, other chromium-nickel stainless steels, chromium stainless steels, carbon and low-alloy steels. A test flow sheet showing preliminary sorting by magnet test, followed by selective separation by chemical drop tests, is given, with full details of procedure for identification of each of the materials named.

E. C. KIRKHAM: 'Rapid Tests for Identifying Alloy Steels,' pp. 73-6.

Description of tests used at Utah Engineering Experiment Station, claimed to be of maximum simplicity and rapidity. Procedure is described for identifying the following elements: nickel, manganese (method believed to be original), molybdenum, chromium, cobalt. Procedure devised for combined testing (by which four different steels can be simultaneously examined for chromium, cobalt, manganese, nickel and molybdenum) is also claimed to be novel, as are certain details of the tests used for stainless and high-alloy steels. Full particulars of technique are given in all cases.

Friction Tests on Metals

See abstract below.

NICKEL

Coefficient of Friction of Nickel

I. SIMON, H. O. MCMAHON and R. J. BOWEN: 'Dry Metallic Friction as a Function of Temperature between 4·2°K. and 600°K.' *Jnl. Applied Physics*, 1951, vol. 22, Feb., pp. 177-84.

The authors give references to some of the major work on friction phenomena, but point out that only one investigator (SCHNURMANN: *Proc. Phys. Soc., Lond.*, 1941, vol. 53, p. 538) has published data on metallic friction at sub-zero temperatures. The work reported in the present paper was designed to supplement information in this temperature region. The measurements made, of friction between two unlubricated surfaces of the same metal, extended down to the temperature of liquid helium: the materials studied were iron, nickel, copper, lead, tin and zinc.

Determinations of shear strength and hardness over the same range of temperature showed that, in spite of the generally large variation of both these properties with temperature, their ratio is, in most cases, dependent to only a slight extent on temperature, and follows fairly closely the change in the static-friction coefficient with temperature. These observations tend to substantiate the adhesion theory of friction proposed by F. P. BOWDEN (*ibid.*, 1943, vol. 14, p. 80).

Full details are given of composition of materials and test procedure; the results are shown in a series of temperature/property curves. (In the case of nickel the static-friction measurements extended to 650°K. (377 °C.); hardness and shear-strength measurements covered the range 0° to 300°K.: −273° to 27°C.)

Factors Affecting Activity of Raney Nickel Catalysts

J. N. PATTISON and E. F. DEGERING: 'Some Factors Influencing the Activity of Raney Nickel Catalyst. III. The Poisoning of Raney Nickel by Halogen Compounds.' *Jnl. Amer. Chemical Soc.*, 1951, vol. 73, Feb., pp. 611-13.

Poisoning of Raney nickel by sulphur compounds was studied by MAXTED and TITT (*Jnl. Soc. Chem. Ind.*, 1938, vol. 57, p. 197; *Nickel Bulletin*, 1938, vol. 11, Nos. 8-9, p. 185) but no previous report of investigation on poisoning by halides has been published.

This paper describes investigations of poisoning by hydrogen chloride and organic halides, and shows that most of the effects observed could be predicted on the basis of known reactivities of these halides. Exceptions to this rule are also discussed.

In general, chlorides and bromides are moderately toxic, while iodides are always highly toxic. The observations made on poisoning by hydrogen chloride indicated that there are at least two distinct types of active surface present on Raney nickel catalysts.

Nickel-Tungstate Catalysts

C. S. ROHRER, J. ROOLEY and O. W. BROWN: 'The Catalytic Activity of Reduced Nickel Tungstate.' *Jnl. Physical and Colloid Chemistry*, 1951, vol. 55, Feb., pp. 211-14.

Report of experiments in which reduced nickel tungstate was used successfully as a catalyst for the reduction of 1-nitropropane to propylamine. Methods for preparation of the catalyst are described, and data are presented to demonstrate the optimum conditions of operation when using it.

Nickel Acoustic Delay Line

T. F. ROGERS and S. J. JOHNSON: 'Nickel Acoustic Delay Line.' *Proc. Inst. Radio Engineers*, 1951, vol. 39, Mar., p. 307.

Abstract of paper presented to Symposium on Industrial Instrumentation, held during the I.R.E. National Convention, March, 1951.

'The effect of a magnetic field upon a nickel acoustic delay line has been studied in an attempt to effect a non-mechanical method of changing its delay time. Changes in delay up to 3 per cent. at 1,000 oersted have been noted and can be explained on the basis of a change in the velocity of propagation of the 1 Mc transverse (shear) sonic waves used. Accompanying the change in velocity is a profound change in the transmittivity throughout the nickel line; at high field strengths output signals have been noted over 100 times in amplitude of those received at H=O.'

Gravimetric Determination of Nickel

R. DUVAL and C. DUVAL: 'Thermogravimetry of Analytical Precipitates. XLIV. Determination of Nickel.' *Analytica Chimica Acta*, 1951, vol. 5, Feb., pp. 71-83.

Using a thermobalance of the Chevenard type, the authors studied the pyrolysis curves of precipitates which have been used in gravimetric estimation of nickel. Fifteen methods for determination have been proposed; a table in the paper summarizes the precipitating reagents, the form in which the nickel is weighed in each of the procedures, and the temperature limits applicable.

The authors recommend the methods involving the use of iodide-iodate, anthranilic acid, dimethylglyoxime, and, in particular, cyclohexanedionedioxime.

Methods for Rapid Identification of Metals: A.S.T.M. Symposium

See abstract on p. 96.

Photocolorimetric Determination of Nickel in Plating Solutions

See abstract on p. 102.

Arc Welding of Nickel-Clad and Stainless-Clad Steel

T. T. WATSON and R. R. ROTHERMEL: 'Aircomatic Welding of Nickel- and Stainless-Clad Steels.' *Welding Jnl.*, 1951, vol. 30, Mar., Suppl. pp. 116-22.

Up to the present time welded fabrication of clad steel has been done, in most cases, by manual electric-arc process. Certain products now being made in clad steel (e.g., piping and long cylindrical vessels) are, however, better suited to automatic welding. This article describes an investigation of the suitability of the Aircomatic process for this purpose.

In this method, developed by Air Reduction Sales Company, a consumable electrode, consisting of the filler metal, is fed into the arc stream, which is completely enveloped by an inert atmosphere. The process can be operated manually, semi-automatically or fully automatically; for full details of technique, reference is directed to a paper published in the *Welding Jnl.*, 1950, vol. 29, pp. 458-82.

In the experiments now reported, the welds were made on nickel-clad steel plate having 10 and 20 per cent. cladding, and on stainless-clad of Types 304, 347 and 410 steels, on which the cladding was 10 and/or 20 per cent. For the nickel-clad welds the electrode was No. 61 nickel type; for the austenitic stainless-clad, 25-20, 19-9, and 19-9Nb electrodes were used, and for the chromium-steel-clad material the 25-20 type only was used.

Experiments, using various techniques, combined with a close study of the influence of the variables involved (joint design, wire, welding current and travel speeds, gas and gas-flow, arc voltage, etc.), indicated that the Aircomatic process can be satisfactorily used for both nickel- and stainless-clad steel. Properties of the joints, as evaluated by free- and side-bend tests, were of a high order. The process has the added advantage, over manual arc welding, that fewer weld passes are required, and that the joint preparation involved is less expensive.

Two procedures were developed for making butt welds on clad plates of $\frac{3}{8}$-in. gauge or below: (1) making a complete weld by depositing a single bead of alloy weld from the backing-steel side of the clad plate; (2) depositing an initial alloy weld from the backing-steel side, and completing the weld with one or more light beads from the clad side. In order to maintain the desired degree of ductility in welding the stainless-clad steels it was found necessary to use 25-20 welding wire for all welds deposited from the backing-steel side. Ductility of the welds made on the chromium-steel-clad specimens (Type 410 cladding) was considerably improved by stress-relief treatment.

Clad plates thicker than $\frac{3}{8}$-in. were manually welded from the backing-steel side with mild-steel electrodes, combined with the use of the Aircomatic process for the clad side. This procedure gave good mechanical properties in the welds. Further experiments are required to establish the maximum plate thickness which can be successfully welded by the Aircomatic process.

Study of the various factors involved showed that the following points are important: (1) fit-up of plates must be such that a root-gap of about $\frac{1}{32}$-in. is maintained, in order to secure control of penetration; (2) the surfaces of the plates to be welded must be free from scale or rust, to prevent porosity and arc instability.

Nickel-containing Spring Materials

See abstract on p. 103.

Spinning of Nickel-containing Materials

See abstract on p. 103.

Welding of Nickel and High-Nickel Alloys

See abstract on p. 106.

ELECTRODEPOSITION AND OTHER COATING METHODS

P.R.P. Process in Electrodeposition of Nickel

'Periodic Reverse Plating of Nickel and Cobalt.' *Electroplating*, 1951, vol. 4, Mar., pp. 89-90.

The article is based on the subject matter of *British Patent* 642,101, granted on Aug. 30, 1950, to Westinghouse Electric International Company. It describes a method of pulsed current plating, using a cycle in which the cathodic period is generally two seconds or less in duration, and the anodic-current period at least 0·002 second.

Nickel-plating solutions of conventional type may be employed; pH range specified is 0·5 to 6·0. Addition agents which may be present include organic sulphonates, such as naphthalene-1, less than 5-disulphonic acid, ammonium sulphate, formaldehyde, nickel formate, sodium sulphate, sodium lauryl sulphate, and ammonium chloride. Gum arabic and gum tragacanth may also be used. Mirror-bright deposits are claimed as producible with current densities from 500 amp./sq. ft. down to a few amp./sq. ft.

For alloy deposition cobalt-nickel anodes are used; alloys containing 80-97 per cent. nickel are specially mentioned, but a wider range of composition is permissible. For deposition of cobalt the bath may contain cobalt sulphate, cobalt chloride, or mixtures of the two, and addition agents similar to those used in the nickel baths.

A figure in the article illustrates an electroplating tank suitable for use in P.R. plating, and a diagrammatic representation is given of the periodic-reverse-current cycle, indicating the direction and density of the current as a function of plating time.

Practical examples of P.R. plating are given, including details of bath compositions and operating

conditions when using (1) a Watts-type nickel solution; (2) a cobalt bright-nickel solution; (3) a high-chloride nickel solution; (4) a cobalt-chloride solution.

Effect of Supersonics on Electrodeposition of Nickel

A. ROLL: 'Effect of Supersonics on Electrolytic Processes. I. Electrodeposition of Nickel in a Supersonic Field.' *Zeitschrift für Metallkunde*, 1950, vol. 41, Oct., pp. 339-43.

A review of earlier literature on the effect of supersonic energy in electrochemical processes is followed by report of an experimental study of the influence of supersonic energy of varying intensity on electrodeposition of nickel from a nickel-sulphate bath. The deposition potential of nickel is lowered, and the current efficiency at high current densities is increased, by the application of supersonic energy. These observations are explicable on the basis of the agitation effect so produced.

The magnetostrictive oscillator and accessories used for production of the supersonic field are described and illustrated.

Discontinuities in Electrodeposited Nickel Coatings

S. C. SHOME and U. R. EVANS: 'Studies in the Discontinuities of Electrodeposited Metallic Coatings. Parts II and III.' *Jnl. Electrodepositors' Tech. Soc.*, 1951, vol. 27, *Advance Copies* 1 *and* 1A, Apr., 1951; 20 pp. and 10 pp.

Part I of this investigation described a qualitative study of the causes of discontinuities in plated coatings. It was found that one important cause was surface irregularity of the basis material; pores were found to be liable to occur along scratch lines made on the basis metal before plating. It is considered that although stresses in the deposit may be the cause of the cracks (i.e., discontinuities which appear spontaneously at places previously coated), they cannot affect pores, which are discontinuities existing at places which have never been coated. It is also observed that internal stresses in the basis metal do not affect porosity.

Experiments on nickel deposits (0·8 μ thick) on steel specimens previously etched anodically in 2*N* hydrochloric acid showed more pores than similar deposits on unetched steel, confirming that enhanced porosity may be attributable to increased roughness of the basis material.

The work reported as Part II was concerned with the manner in which the uncovered area (the area of porosity) diminishes as the mean thickness of a deposit is increased, and the mechanism of coverage.

Two methods are described for measuring the total uncovered area (*a*) of a plated specimen. (It is pointed out that most methods which have been proposed for measurement of porosity furnish simply the number of pores.) One of the new methods depends on the total iron passing into solution when a nickel-plated specimen is joined to copper gauze of an area so large that any further increase in area causes no appreciable increase in rate of passage of iron into the liquid. The other is based on measurement of the current flowing between the copper and the specimen under similar conditions. A straight line is obtained when log a is plotted against t^2, where t is the time of plating at constant current density, but not when it is plotted against t or t^3. The results, viewed in the light of an earlier theoretical discussion by one of the authors, suggest that deposition starts from pre-existing nuclei, and that if the initial number of nuclei can be increased the porosity remaining after any given time of plating should be reduced.

Practical recommendations for production of pore-free deposits, made on the basis of the results reported, include provision of a clean and smooth surface on the basis material, freedom of the plating solution from suspended impurities, use of a plating bath having a high value of $d\eta/dI$ (where η is the polarization at current density I): and the use of a short strike treatment at high current density, followed by plating at lower current density.

Part III opens with a review of the limitations of methods which have been proposed for evaluation of porosity in metallic coatings (ferroxyl test, hot-water test, salt-spray test). As the ideal, the reagent chosen for a porosity test should not attack the coating, and should contain a cathodic stimulator, thus shortening the test period. It should also help the precipitation of iron in a visible form, enabling the pores to be counted. None of the three tests mentioned entirely fulfils these requirements.

An improved test described in this paper is based on the use of a sodium-chloride solution containing a small quantity of hydrogen peroxide. Rust spots appear readily on thin nickel-plated specimens immersed in this mixture; the hydrogen peroxide enhances corrosion of the steel by stimulating the cathodic reaction, and also converts ferrous ions at the pores to visible rust spots, and there is less attack on the nickel than in the ferroxyl test.

The potential of nickel-plated steel specimens moves in the cathodic direction as the thickness of the coatings increases. The change of potential is small in the presence of sodium chloride or ferroxyl solution, but is marked if the sodium-chloride solution contains hydrogen peroxide.

Nickel Plating of Tubes using Insoluble Anodes

A. W. HOTHERSALL and G. E. GARDAM: 'Electrodeposition of Nickel in the Bores of Tubes, using Insoluble Anodes.' *Jnl. Electrodepositors' Tech. Soc.*, 1951, vol. 27; *Advance Copy* 7, Apr., 1951; 15 pp.

The authors describe a method developed in the Research Department, Woolwich* before the war and applied in several plants during the war period.

In the methods generally employed for electrodeposition of nickel, composition of the bath is maintained by use of a soluble nickel anode. Application of such a method to internal coating to a tube involves use of an anode consisting of a rod of solid nickel, or of some other metal coated with nickel. Such an arrangement has certain serious disadvantages, which are reviewed.

*Now *Armament Research Establishment.*

The method developed to obviate such inconveniences, which is the subject of this paper, involves the use of an insoluble anode made of, or coated with, lead. A nickel-sulphate/boric-acid solution, free from chloride, is circulated through the tube, and its composition is maintained by continuous or periodic addition of nickel hydroxide in a finely divided condition.

The success of the process depends upon proper attention to detail, in particular to the finish of the surface of the tube, to the diameter, material and straightness of the anode, and to the correct rate of flow of the solution in relation to the size of the tube and the current density of deposition. Nickel deposits 0·05 in. in thickness have been built up inside tubes 6 ft. in length and initially 4 in. in diameter. The deposits normally have a diamond hardness number of approximately 200, an ultimate tensile strength of about 30 tons/sq. in. and an elongation of approximately 30 per cent.

It is pointed out that, since the process requires special apparatus and the attention of experienced staff, it is not highly suitable for use on single jobs of appreciable area. It has, nevertheless, proved valuable for rectification of expensive tubes which had been overbored, and for tubes required for certain chemical engineering purposes. For such purposes it can be recommended.

Relationship between Structure and Brightness in Electrodeposited Nickel Coatings

G. L. CLARK and S. H. SIMONSEN: 'The Relationship between Orientation, Grain Size and Brightness in Nickel Electrodeposits.' *Jnl. Electrochemical Soc.*, 1951, vol. 98, Mar., pp. 110-15.

Two major theories have been proposed to explain the brightness of some electrodeposits: (1) that if the grain size of the deposits is smaller than the wavelength of light, the deposit will be bright, and (2) that if there is a high degree of preferred orientation, so that the crystal faces presented to the surface are essentially parallel, even large-grained deposits will be bright. The present author gives a summary review of the literature on these theories, with supporting references.

In an attempt to clarify the position, and confirm or refute the above theories, examination was made of a large number of nickel deposits prepared under varied conditions of current density, and bath composition, and of varying thickness. Baths including brightening addition agents were used, as well as unmodified baths. The basic solution was of the Watts type, containing, in most cases, a small amount of wetting agent or non-pitting medium. In most cases the deposits were made on brass; a few additional specimens were plated on steel. Full details of the individual samples are given.

X-ray diffraction data reported show that [100], [110], [100]+[110], [112], [120], and [120]+[110], fibre axes, as well as a random distribution of crystals, were observed in matte, semi-bright and bright nickel electrodeposits; the predominant orientation was the [100].

In the large number of plated panels examined, no correlation could be found between brightness and orientation of the crystals.

It is concluded that the property of brightness in nickel deposits is not due largely to grain size, since the X-ray grain sizes of matte, semi-bright and bright deposits were of the same order of magnitude.

Thickness Testing of Electrodeposited Nickel Coatings

H. J. READ and F. R. LORENZ: 'Methods for Testing Thickness of Electrodeposits. II. Comparison of Methods for Nickel on Steel.' *Plating*, 1951, vol. 38, Mar., pp. 255-63.

Report issued under the aegis of A.E.S. Research Project 7.

The extensive literature of thickness testing of electrodeposits is concerned almost exclusively with investigation of the accuracy and reproducibility of individual methods, but the authors have found only one instance (EGGINTON, *Jnl. Electrodepositors' Tech. Soc.*, 1947-48, vol. 23, pp. 191-202) in which a single coating on a given basis metal has been subjected to various thickness tests on a comparative basis.

The programme of tests by the American Electroplaters' Society comprised preparation of a series of panels, in duplicate, having a variety of coating thicknesses covering the range likely to be encountered in decorative and in protective plating, and the measurement of these coating thicknesses by five methods which have gained some measure of general acceptance and usage.

The techniques of measurement chosen for use were: Magne-gage, B.N.F. jet test, the microscopical method, stripping and cathode - gain - in - weight (calculated). Thickness ranged (in eight steps) from 0·0001 to 0·005 in. (2·5 to 127μ). All panels were plated from a Watts-type nickel bath, under strictly controlled similar conditions.

Tables show results of the individual series of measurements. Correlation and statistical treatment lead to the conclusion that the reproducibility of the Magne-gage, B.N.F. jet, microscopical and stripping methods is acceptable for most purposes, except when the microscopical method is used for deposits of less than about 0·3 mil (7·5μ).

With regard to the advantages and limitations of the individual methods, the following comments are made:—

'There is, in general, little to choose between the Magne-gage, the jet test and the microscopic method if certain limitations are recognized. The Magne-gage must be suitably calibrated for the metal being measured. The jet test is not satisfactory for thicknesses of 2 mils (50μ) or more. The microscopic method is unreliable for deposits of 0·5 mil (13μ) or less. It is interesting to note that the microscopic method, which has so often been considered to be suitable for a reference standard, is no better than the others for thicknesses under 2 mils (50μ).

'The excellent correlation between the calculated thickness and the stripping results is extremely interesting. It is well known that the Magne-gage and the jet test are sensitive to structural and other characteristics of the deposit and should be calibrated

against standards which have been prepared in the solution and under the conditions which are used in plating the work which is to be measured.'

Electrodeposition of Nickel-Rhenium Alloys

L. E. NETHERTON and M. L. HOLT: 'Electrodeposition of Rhenium-Nickel Alloys.' *Jnl. Electrochemical Soc.*, 1951, vol. 98, Mar., pp. 106-9.

Fuller account of work referred to from abstract source in *Nickel Bulletin*, 1951, vol. 24, No. 2, p. 33.

The paper describes experiments in which rhenium-nickel alloys were deposited from an ammoniacal citrate bath and from nickel-plating baths containing potassium perrhenate. The ammoniacal citrate bath was used to study the effects of bath composition, pH, temperature and current density, on cathode efficiency and alloy composition. From a bath of this type, containing 56 g./L. of $NiSO_4.6H_2O$, 10 g./L. of $KReO_4$ and 66 g./L. of citric acid, operated at 70°C. and 5 amp./sq. dm., an alloy containing 78 per cent. rhenium was deposited, with an efficiency of about 90 per cent.

Tests of the rhenium-nickel deposits against a number of common corrosive reagents indicated no outstanding characteristics in this respect, but in air the deposits remained bright over a test period of three months.

Electrodeposition of Nickel-Tin Alloys

N. PARKINSON: 'The Electrodeposition of Bright Tin-Nickel Alloy Plate.' *Jnl. Electrodepositors' Tech. Soc.*, 1951, vol. 27; *Advance Copy* 4, Apr., 1951; 23 pp.

The process described, developed by The Tin Research Institute, is the subject of patents in Great Britain and other countries.

Theoretical considerations on which the programme of research was based are reviewed and a detailed account is given of a study of the effect of variables in composition of the plating baths and operating conditions.

The electrolyte developed as optimum contains stannous chloride, nickel chloride, and fluorides, a preferred composition being (g./L.) stannous chloride 50, nickel chloride 300, sodium fluoride 28, ammonium bifluoride 35. At a working temperature of 65°C., and an average cathode current density of 25 amp./sq. ft., bright plating is obtained, over irregular objects, at a current efficiency in the region of 100 per cent. The composition of the deposit is independent, to a large extent, of variations in current density and temperature, and variations of 20-30 per cent. in the content of either tin or nickel in the electrolyte cause only insignificant changes in the composition of the alloy deposited. Total-fluorine content of the bath is the major factor affecting composition of the deposit.

A qualitative study of factors affecting the brightness of the coatings showed that the broadest bright-plating range is obtained at high, rather than at low, temperatures and that the presence of free hydrofluoric acid and of an alkali-metal ion (preferably sodium) is necessary for the best results.

Replenishment of the bath may be effected either by using alloy anodes or by employing separate tin and nickel anodes supplied at different voltages. With separate anodes precautionary measures are necessary to minimize the effect of chemical reaction between the tin anodes and the electrolyte. Full details are given of equipment and operating conditions for large-scale tin-nickel deposition.

The alloy deposited is an intermetallic compound, and is therefore hard. It has a bright and pleasing appearance, and in some lights shows a slightly pink tone. It is entirely free from the blue coloration associated with chromium, and from the more yellow tone of nickel plating; it is therefore considered that such deposits should have interest in the decorative-plating field.

Tests on the corrosion-resisting properties of the tin-nickel alloy deposit are not yet complete, but the work done to date has indicated that the plating is highly resistant to tarnishing, under both indoor and out-of-door conditions. It is also resistant to attack by cold mineral acids, and is almost immune from attack by inhibited hydrochloric acid and by hot concentrated nitric acid.

On non-ferrous basis materials a thickness of 0·0005 in. of tin-nickel alloy is believed to be adequate for all ordinary service, and there is some evidence that such thickness ensures reasonable freedom from porosity. On steel bases a copper undercoat should be used, with a final 0·0005 in. thickness of tin-nickel alloy.

An appendix to the paper, by J. W. PRICE, is entitled 'Analytical Control of the Tin-Nickel Electrolyte'. This contains working instructions for determination of stannous and stannic tin, nickel, total fluorine, sodium, and ammonium, in the plating bath.

Structure of Nickel-Tin Electrodeposited Coatings

H. P. ROOKSBY: 'An X-ray Study of Tin-Nickel Electrodeposits.' *Jnl. Electrodepositors' Tech. Soc.*, 1951, vol. 27, *Advance Copy* 5, Apr., 1951; 8 pp.

The paper describes the structure and textural properties of electrodeposited tin-nickel alloys made by the methods reported in Parkinson's paper (see previous item).

A metastable nickel-arsenide type of structure, similar to that of γ' Ni_3Sn_2, characterizes the alloy electrodeposit. The hexagonal structure cell constants $a_o = 4 \cdot 15$Å, $c_o = 5 \cdot 10$Å, $c/a = 1 \cdot 23$, differ appreciably from established values for Ni_3Sn_2. The differences result from the change in composition from Ni_3Sn_2 towards NiSn induced by the conditions of electrodeposition. The alloy deposit is stable up to 300°C., but decomposes on heating above this temperature.

A strongly marked preferred-orientation texture is found in bright tin-nickel electrodeposits, and an analogy with bright speculum is evident.

Electroplating of Stainless Steel

H. H. HEAD: 'Plating Stainless Steel.' *Metal Industry*, 1951, vol. 78, Apr. 13, pp. 287-90.

This article comprises a useful summary of practical information on a subject on which the literature is relatively sparse.

The sequence of operations involved in electroplating stainless steel is described, with recommendations as to materials and technique in—

(1) scale removal (by blasting, tumbling, pickling, molten-salt treatment, wire-brushing);
(2) polishing;
(3) racking;
(4) cleaning;
(5) activation (tabular summary of procedure for sulphuric-acid, nickel-chloride/hydrochloric-acid, and hydrochloric-acid treatments);
(6) plating (compositions of solutions and operating conditions are given for electrodeposition of cadmium (over nickel strike), copper, chromium, gold, nickel and silver. Special attention is directed to precautions necessary in chromium plating);
(7) stripping.

An appendix gives a broad classification of the grades of stainless steel commercially available, and the mill finishes in which they are usually obtainable.

Plating of Aluminium: the Zincate Pre-Treatment

G. L. J. BAILEY: 'Electrodeposition on Aluminium: A Study of the Zincate Process.' *Jnl. Electrodepositors' Tech. Soc.*, 1951. vol. 27, *Advance Copy* 10, Apr., 1951; 22 pp.

The paper is based on work done in the laboratories of the British Non-Ferrous Metals Research Association, previously made available to members of the Association in a series of confidential reports.

Following a brief note on the intrinsic difficulties associated with electroplating of aluminium, a review is made of major recent literature, particular attention being directed to reports by BULLOUGH and GARDAM (*Jnl. Electrodepositors' Tech. Soc.*, 1947, vol. 22, p. 169) and KELLER and ZELLEY (*Proc. 36th Annual Convention, Amer. Electroplaters' Soc.*, 1949, p. 143). Conclusions to be drawn from these two investigations are summarized, indicating that there is a connexion between the useful properties of coatings deposited on zincate-dipped aluminium and the nature of the zinc deposit on which the coatings are formed. The nature of the zinc deposit (its weight and porosity) is influenced by three factors:—

(1) composition of the aluminium alloy base;
(2) 'conditioning' procedure applied to the basis metal;
(3) composition of zincate solution and conditions of immersion.

The author describes experiments in which the effects of these variables were studied. The deposits superimposed on the zincate-treated material were in all cases made from a Watts-type nickel bath. The report of the tests is prefaced by a discussion of methods used to assess adhesion strength.

The most interesting feature of the data presented is the evidence obtained of the predominating influence exercised by the composition of the zincate solution. Such effects were anticipated, on the basis of theoretical considerations which are discussed in the paper.

The final section of the paper contains a consideration of the theory of mechanism of adhesion for the zincate process.

Chromatographic Analysis of Nickel-Plating Solutions

F. H. BURSTALL, N. F. KEMBER and R. A. WELLS: 'Inorganic Chromatography on Cellulose; Some Applications to the Analysis of Nickel Plating Baths.' *Jnl. Electrodepositors' Tech. Soc.*, 1951, vol. 27, *Advance Copy* 11, Apr., 1951; 12 pp.

The separation of pure substances from a mixture in solution is, in many cases, a difficult process, but during the past few years substantial progress has been made in the development of chromatographic procedures for separation of inorganic materials. The principles of the method, which depends on selective extraction of substances by solvents, in presence of solid adsorbents, are briefly summarized as an introduction to this paper, which describes the application of the principles to analysis of nickel-plating solutions.

Cellulose has, to date, proved to be by far the most suitable adsorbent for this purpose, and the major factor involved in securing satisfactory results is correct selection of the solvent medium, which must be determined by experiment, according to the metals known to be present in the solution to be analysed. In the work described acetone containing 2 per cent. v/v of concentrated hydrochloric acid (d. 1·18) was used. The extractions described were carried out on a synthetic plating solution of the following composition:—

$NiSO_4.7H_2O$	105 g.
$NiCl_2.6H_2O$	15 g.
NH_4Cl	15 g.
H_3BO_3	15 g.
Water	to 1,000 ml.

To this solution the various impurities which were to be extracted were added in the form of their sulphates. Particulars are given of the extraction of cobalt, iron, copper, zinc, manganese and cadmium. The results obtained indicate that the method provides an accurate and rapid means for estimation of impurities in nickel-plating baths.

The paper also records paper-strip separation from chloride solutions, using procedure described by the authors in the *Journal of the Chemical Society*, 1950, p. 516. The solvent employed was acetone containing 5 per cent. v/v of water and 8 per cent. v/v of hydrochloric acid (d. 1·18). Nickel, manganese, cobalt and zinc were thus separated, on strips of filter paper. Similarly, a methyl propyl ketone solvent was used for quantitative separation and estimation of nickel, manganese, cobalt, copper and iron. Work done with both of these solvents has indicated the possibility of using them for analysis of nickel-plating solutions.

Photocolorimetric Determination of Nickel in Plating Solutions

G. C. H. STONE: 'Photocolorimetric Method for the Analysis of Nickel in Nickel Plating Baths.' *Metal Finishing*, 1951, vol. 49, Feb., pp. 44-8.

D. G. FOULKE recently suggested that the photoelectric colorimeter might be employed to determine the nickel content of plating baths, and for estimation

of traces of metal impurities in such solutions (*ibid.*, 1949, vol, 47, Oct., pp. 58-64, 67). He reported, however, that although a considerable amount of data had been accumulated, a complete investigation of all variables had not been made. The present paper describes a study of the influence, on colour of the bath, of the following variables:—nickel-sulphate, nickel-chloride, ammonium-chloride, sodium-sulphate and boric-acid contents, and hydrogen-ion concentration. The effects of various brighteners and non-pitting additions were also considered.

Details are given (with diagram) of the Leitz Industrial Photometer used, and of the experimental procedure: results of the individual series of determinations are reported.

The results of the experiments show that nickel content in the baths studied may be determined by the photocolorimetric method, within the limits of accuracy required for control purposes. Nickel-chloride and nickel-sulphate solutions were found to have a colour which was dependent only on the concentration of the nickel ion. Within the limits of concentration encountered in nickel-plating baths, ammonium chloride and sodium sulphate had no effect on colour. Variations in boric-acid content and in pH had a minor effect, not exceeding 3 per cent.

It is urged that the simplicity and rapidity of the method, combined with its adequate accuracy, should lead to widespread use for control purposes.

Methods for Rapid Identification of Metals: A.S.T.M. Symposium

See abstract on p. 96.

NON-FERROUS ALLOYS

Solidification Behaviour of Copper-Nickel Alloys

R. E. CECH and D. TURNBULL: 'Microscopic Observation of the Solidification of Cu-Ni Alloy Droplets.' *Trans. Amer. Inst. Mining and Metallurgical Engineers*, 1951, vol. 189, pp. 242-3; *T.P.* 3038E; *Jnl. of Metals*, Mar., 1951.

In an earlier investigation the authors studied the supercooling behaviour of pure liquid metal droplets (*Jnl. Applied Physics*, 1950, vol. 21, p. 804). This second paper describes a similar study on copper-nickel alloys, a system which presented interest for such an investigation due to the fact that the component elements are miscible in all proportions, in both the liquid and the solid state.

Nine alloys were used, ranging from 88·93 to 10·28 per cent. copper, and solidification behaviour was studied as a function of composition, by means of a high-temperature microscopic technique previously described.

The ratio of the amount of supercooling $(\Delta T-)_{max.}$ to the absolute liquidus temperature was found to be $0{\cdot}18\pm0{\cdot}01$, which checks closely the value of $0{\cdot}18\pm0{\cdot}02$ for the ratio of $(\Delta T-)_{max.}$ to the absolute melting temperature found for pure metals.

A cross-section of a supercooled particle displayed segregation, indicating that the heat of fusion was probably sufficient to raise the droplet to the equilibrium freezing temperature and allow a portion of the particle to solidify by normal dendritic growth.

It was demonstrated that the temperature dependence of the nucleation rate was about as large as for pure metals.

Nickel-containing Spring Materials

P. DOYEN: 'Ferrous and Non-Ferrous Nickel-containing Spring Materials.' *Rev. du Nickel*, 1951, vol. 17, Jan.-Mar., pp. 10-23.

A review of nickel-containing alloys and steels the properties of which render them peculiarly suitable for use in springs of various types. Materials considered: nickel, 'Z' nickel, Monel, 'K' Monel, Inconel, Nimonic 80, corrosion-resisting nickel-chromium steels, Ni-Span and Elinvar (nickel-iron-base alloys), Elgiloy (complex nickel-cobalt-chromium-iron alloy), and low-alloy steels containing nickel. Compositions, mechanical and physical properties, and uses of the individual materials are detailed.

The review is made in two sections, relating, respectively, to (1) springs operating under 'special' conditions, e.g., at elevated temperatures, or in contact with corrosive media, and (2) those working at normal temperatures, and not subject, in service, to corrosive or other conditions likely to cause deterioration, or require materials having unusual properties.

Spinning of Nickel-containing Materials

L. F. SPENCER: 'Why Not Spin It ?' *Iron Age*, 1951, vol. 167, Mar. 1, pp. 105-9.

The writer urges the usefulness of spinning as a production method, and discusses the various materials which can be fabricated by spinning. Factors involved in selection of material and procedure are reviewed, as affecting aluminium alloys, magnesium alloys, lead- and zinc-base alloys, stainless steels (in which the work-hardening characteristics require special consideration), nickel, Monel, and Inconel.

Some of the main recommendations made are summarized below:—

Chucks: Although wood makes an inexpensive chucking material for experimental purposes, hard nickel-chromium cast iron or steel is to be much preferred for long-production runs, and in order to ensure close tolerances and good surface finish. A cast iron containing carbon 3·0, nickel 2·5-3·0, chromium 0·75-1·0, silicon 1·2-1·5, per cent., heat-treated to maximum hardness, has been found particularly suitable. Aluminium or magnesium chucking is preferred for spinning magnesium, and bronze spinning tools may be used for handling stainless steel. For spinning Monel, Inconel and nickel, tools should be broader and flatter than those normally used for softer materials.

Avoidance of Re-Working: Re-working over the same surface should be avoided as far as possible, especially on materials having a high rate of work hardening. In spinning high-nickel alloys a speed approximately half to three-quarters of that used for spinning the

(*continued on p. 106*)

STEEL TYPE	'18/2' Cr-Ni	Normal '18/8' Cr-Ni	Low Carbon '18/8' Cr-Ni	Deep Drawing Quality '13/13' Cr-Ni	Ti- or Nb-Stabilized '18/8' Cr-Ni	M
Typical Analysis per cent. / Standard Specification	C 0·2 Si 0·2 Mn 0·3 Cr 17·5 Ni 1·5 — —	C 0·12 Si 0·5 Mn 0·4 Cr 18·0 Ni 8·0 — —	C 0·06 Si 0·5 Mn 0·4 Cr 18·5 Ni 9·0 — —	C 0·1 Si 0·3 Mn 0·4 Cr 13·0 Ni 13·0 — —	C 0·1 Si 0·5 Mn 0·4 Cr 18·0 Ni 9·0 Ti 5×C or Nb 10×C	
1. B.S.970 Wrought Steels for Automobile and General Engineering	En57	En58A	En58E	En58D	En58B En58C En58F En58G	
2. B.S.1449 Steel Plate, Sheet and Strip	En57	En58A	En58E	En58D	En58B En58C En58F En58G	
3. B.S.1554 Rust, Acid and Heat-Resisting Wire	En57	En58A	En58E	En58D	En58B En58C En58F En58G	
4. (*a*) B.S.1630 - 1632 Corrosion-Resisting Alloy Steel Castings (*b*) B.S.1648 Heat - Resisting Alloy Steel Castings		B.S.1631 Grade A B.S.1648 Grade D			B.S.1631 Grade B	
5. B.S.1501 - 1506 Steels for Chemical and Petroleum Industries (i) B.S.1501 Plates, Sections and Bars (ii) B.S.1503 Forgings (iii) B.S.1504 Castings (iv) B.S.1506 Bar for Bolting		B.S.1501-801 Grade A B.S.1503-801 Grade A B.S.1504-801 B.S.1506-801 Grade A	B.S.1501-801 Grade B B.S.1503-801 Grade B B.S.1506-801 Grade B		B.S.1501-821 Grade A & B B.S.1503-821 Grade A & B B.S.1504-821 B.S.1506-821 Grade A & B	B B B B
6. B.S.1507-1508 Steel Pipes and Tubes for Pressure Vessels for Chemical Industry (i) B.S.1507 Steel Pipes (ii) B.S.1508 Steel Tubes		B.S.1508-801			B.S.1507-821 B.S.1508-821	
7. B.S.1607 Wrought Steel Pipe for the Petroleum Industry			B.S.1607-P8A		B.S.1607-P8B (Ti) B.S.1607-P8D (Nb)	B
8. British Standards (Aircraft Series) (i) Bars and Forgings (ii) Tubes (iii) Wire Rope	2S80				S110 T55, T58 W10, W11	
9. Ministry of Supply (Aircraft D.T.D. Series) (i) Bars (ii) Tubes (iii) Sheet and Strip (iv) Wire and Wire Rope	D.T.D.715 (for nuts) D.T.D.60B D.T.D.163A	D.T.D.189, 236		D.T.D.688	D.T.D.571 D.T.D.166B 171B, 571, 712 D.T.D.549, 571	
10. Corresponding American Iron and Steel Institute Types (A.I.S.I. Series)	A.I.S.I.431	A.I.S.I.302	A.I.S.I.304		A.I.S.I.321 (Ti) A.I.S.I.347 (Nb)	

NOTE.—Although the specifications grouped beneath each type of s

OMIUM-NICKEL CORROSION- AND HEAT-RESISTING STEELS

r Nb-ilized 3/8' -Ni	Mo-Bearing '18/8' Ni-Cr	Ti-Stabilized Mo-Bearing '18/8' Cr-Ni	'13/13/3' Cr-Ni-W	'24/12' Cr-Ni	'25/20' Cr-Ni	'37/15' Cr-Ni
0·1 0·5 0·4 18·0 9·0 5×C or 10×C	C 0·08 Si 0·3 Mn 0·5 Cr 18·0 Ni 9·0 Mo 2·5	C 0·08 Si 0·3 Mn 0·4 Cr 18·0 Ni 9·0 Mo 2·5 Ti 0·4	C 0·4 Cr 13·0/15·0 Si 1·0/2·0 Mn 1·0 max. Ni 13·0/15·0 W 2·0/3·0	C 0·2/0·4 Cr 20/24 Si 1·0/2·5 Mn 1·0 max. Ni 10·0/12·0 W 2·0/3·0	C 0·2 max. Cr 23·0/26·0 Si 1·0/2·0 Mn 2·0 max. Ni 20·0/22·0	C 0·2/0·4 Cr 15/18 Si 1·0/2·5 Mn 0·5/1·5 Ni 35/38
En58C En58G	En58H En58J	En58H En58J	En54	En55		
En58C En58G	En58H En58J	En58H En58J				
En58C En58G	En58H En58J	En58H En58J				
31 Grade B	B.S.1632 Grade A	B.S.1632 Grade B		B.S.1648 Grade E	B.S.1648 Grade F	B.S.1648 Grade H
501-821 de A & B 503-821 de A & B 504-821	B.S.1501-844 B.S.1503-844 B.S.1504-844	B.S.1501-845 Grade A & B B.S.1503-845 Grade A & B B.S.1504-845				
506-821 de A & B	B.S.1506-844	B.S.1506-845 Grade A & B				
507-821 508-821		B.S.1507-845 B.S.1508-845			B.S.1508-825	
607-P8B (Ti) 607-P8D (Nb)	B.S.1607-P8E	B.S.1606-P8E				
T58 W11			S111	S108	S109	
D.571					D.T.D.491	
D.166B , 571, 712 D.549, 571					D.T.D.493 D.T.D.489	
.321 (Ti) .347 (Nb)	A.I.S.I.316			A.I.S.I.309	A.I.S.I.310	

h each type of steel are basically similar, they are not necessarily identical.

same shape from softer materials should be used. 18-8 stainless steel should be spun at one-quarter to one-half the speed used for copper.

Lubrication: Lubricants should be heavy-bodied, to withstand the high pressure and temperatures involved in shaping, and, wherever possible, should be easily removable in the cleaning operations. Complete removal is imperative in the case of stainless steels, since traces of lubricant or tool material left on the steel may give rise to serious intergranular corrosion on subsequent annealing.

Recommendations are made on lubricants for individual materials. For stainless steel an oil-bearing type is preferred for spinning heavy stock, and for lighter gauges yellow laundry soap or water-soluble lubricants are suitable. For nickel and the high-nickel alloys yellow soap is most frequently used; beeswax, tallow, or a mixture of the two has also proved satisfactory. Lubricants containing lead or sulphur must be avoided if the spun parts are to be annealed, and, as with stainless steel, rigorous cleaning is imperative.

Miscellaneous Recommendations on Procedure: The following points are made:—

'With Monel, an increase in height of 1-1½ in. constitutes one operation when the spinning is done with a bar tool. Where mechanical spinning is employed, about twice that depth can be obtained. In the early stages of spinning in nickel or 'L' nickel it is usually possible to spin twice or three times the depth of a Monel operation before annealing is required.

'In a sequence of operations where insufficient intermediate chucking is provided, the material is subjected to a large degree of cold work. With the high-nickel alloys, this condition may result in either spinning a 'knuckle' or pulling the material to form a pebbled surface. It is practically impossible to smooth out the former, or to correct the latter by annealing. High-nickel alloys will not stretch as much as the softer metals during spinning; slightly larger blanks are therefore necessary.

'Spinning is often used on stainless steel as an operation subsequent to drawing, either to perfect contour or to form odd shapes, necks, special flanges and beads. Because of its tendency to harden through cold work, stainless steel requires considerable power to spin, and may wrinkle along the edges. This can be prevented to some extent by turning up a flange on the edge of the blank and working the centre metal first.

'Care must be taken to prevent stress cracking when working stainless steel. Leaving 1 or 2 in. of unworked rim metal until spinning is near completion will aid considerably in combating this condition.'

Welding of Nickel and High-Nickel Alloys

R. M. WILSON: 'Nickel Portion of A.W.S. 1950 Educational Lecture Series.' *Welding Jnl.*, 1951, vol. 30, Mar., pp. 247-56.

This lecture, delivered as one of a series at the October, 1950, Annual Meeting of the American Welding Society, reviews welding procedure suitable for alloys containing 50 per cent. and over of nickel. The following materials are specifically covered:—

Wrought: Nickel, low-carbon nickel, Duranickel, nickel-clad steel; Monel, 'K' and 'R' Monels, Monel-clad steel; Inconel, Inconel 'X', Inconel-clad steel.

Cast: Nickel; Monel, 'S' and 'H' Monels; Inconel.

Nominal compositions of these materials are given, together with average physical constants and mechanical properties, and the work-hardening characteristics of the wrought materials are illustrated by a curve showing effects produced by reductions up to 70 per cent. A general warning with regard to avoidance of sulphur- and lead-contamination when handling the high-nickel alloys is emphasized by illustrations showing deterioration produced by contact with these elements.

The main lecture comprises a practical review of procedure for welding. Applicability of the various methods to the respective materials is indicated and technique is recommended. The survey covers the following welding methods: metal-arc, inert-gas metal-arc, submerged-arc, atomic-hydrogen, oxy-acetylene, oxyacetylene-pressure, resistance. Silver-, bronze- and copper-brazing are also discussed in relation to the high-nickel materials, and thermal cutting methods applicable to them are considered. A further section deals with joining of nickel alloys to dissimilar materials. Finally, notes are added on precautions which must be observed in welding for high-temperature applications.

A highly-selective, but practically useful, *bibliography* of nine references supports the lecture.

Electrodeposition of Nickel-Rhenium Alloys

See abstract on p. 101.

Structure of Nickel-Tin Electrodeposited Coatings

See abstract on p. 101.

Aluminium-rich Aluminium-Iron-Cobalt-Nickel Alloys

M. B. WALDRON: 'The Stability of the Co_2Al_9-Type Structure in the Aluminium-rich Alloys of the Aluminium-Iron-Cobalt-Nickel System.' *Jnl. Inst. Metals*, 1951, vol. 79, pp. 103-16; *Advance Copy* 1300; *Monthly Jnl.*, Apr., 1951.

In the aluminium-rich portion of the system aluminium-iron-cobalt-nickel there exists a quaternary phase $(Fe, Co, Ni)_2Al_9$, for which the range of homogeneity includes terminal compositions Co_2Al_9 and $FeNiAl_9$. Electron: atom (e/a) ratios of 2·12 and 2·16, respectively, can be assigned to these compositions, assuming that cobalt, iron, and nickel may accept, respectively, 1·71, 2·66 and 0·61 electrons per atom from the structure as a whole. The iron-rich boundary of the phase, which corresponds to the lower limit of the e/a ratio, starts as a straight line of constant e/a ratio 2·07 from the Co_2Al_9 region, but changes direction sharply when half the cobalt atoms have been replaced by iron and nickel atoms, and approaches linearly a value giving an e/a ratio of 2·14.

The lower limiting e/a ratio of a phase is determined by the point at which the depletion of electrons reduces the binding energy of the structure relatively to that of an alternative phase. Thus, compositions in the region of Co_2Al_9 appear to be more

stable than those in the region of $FeNiAl_9$, since Co_2Al_9 permits solution of iron until the *e/a* ratio has been reduced from 2·12 to 2·07, compared with a reduction from 2·16 to 2·14 in the region of $FeNiAl_9$. Melting points are further indices of stability: Co_2Al_9 melts at 943°C. and forms a eutectic with $FeAl_3$ and the aluminium-rich solid solution; $FeNiAl_9$ is formed peritectically from $FeAl_3$ at 809°C.

An experimental technique has been devised which makes possible the determination of the composition of the quaternary phase at the point where the eutectic relationship with $FeAl_3$ changes to the peritectic reaction. It is believed that the technique may prove useful for investigating other systems in which a peritectic reaction must be studied.

Nickel-Indium Alloys

E. HELLNER: 'The Nickel-Indium System.'
Zeitschrift für Metallkunde, 1950, vol. 41, Nov., pp. 401-6.

A detailed report on investigation of the system by means of thermal analysis, microscopical examination and X-ray investigation. A constitutional diagram is proposed on the basis of the observations made. The author's results are correlated with the relevant literature.

Methods for Rapid Identification of Metals: A.S.T.M. Symposium

See abstract on p. 96.

CAST IRON

Analysis of Cast Iron and Other Foundry Materials: Textbook

W. WESTWOOD and A. MAYER: 'Chemical Analysis of Cast Iron and Foundry Materials.' *Published by George Allen and Unwin, Ltd.*, London, 1951. 565 pp. Price 42/-.

This volume comprises the most extensive and authoritative handbook yet published on the subject. The authors have, in the course of their professional work, been in contact with individuals and organizations from whom much valuable information could be obtained, and have themselves for years been engaged in dealing with analysis of the materials covered in their book. Experience and knowledge so gained has been supplemented by a detailed study of the relevant literature, to which due reference is given in the text. The material contained is set out in a clear and easily accessible manner, and the volume should be of lasting value to all engaged in sampling and analysis of foundry materials.

Scope of the respective chapters is shown below:—

I. Introduction: Laboratory Practice and Apparatus.
II. Sampling and Analysis of Cast Iron, including sections on determination of all the elements normally present, and the alloy constituents present in 'special' cast irons.
III. Sampling and Analysis of Ferro-Alloys, Inoculants and Ladle Additions.
IV. Sampling and Analysis of Iron Ore and Used Annealing Ore.
V. Analysis of Cupola, Rotary-Furnace, and Blast-Furnace Slags.
VI. Sampling and Analysis of Sand, Siliceous Refractories and Fire Bricks.
VII. Sampling and Analysis of Coke.
VIII. Analysis of Coal Dust.
IX. Sampling and Analysis of Linseed Oil.

Appendices contain much useful information on furnace construction, temperature measurement, laboratory equipment and reagents, indicators for pH determination, typical compositions of cast irons of ordinary and special types, compositions of ferro-alloys, ladle additions and inoculants: British Chemical Standards, metric units, conversion factors, etc. A list of reference books is also given, and both author and subject indexes are detailed.

CONSTRUCTIONAL STEELS

Influence of Austenitizing Temperature on Properties of Nickel-Alloy Steels

J. A. WHEELER, V. KONDIC and T. KO: 'Effect of Initial Heating Temperature on the Mechanical Properties of Nickel-Chromium-Molybdenum Steels.'
Jnl. Iron and Steel Inst., 1951, vol. 167, Mar., pp. 301-8.

The work described was carried out as part of a study of conditions involved in the welding of air-hardening steels. It is pointed out that the characteristics of the temperature cycle to which such material is subjected are outside those of normal heat-treatment conditions, and that, in view of the susceptibility to cracking in the heat-affected area near the weld, a close investigation of the influence of such thermal conditions is desirable.

Effects of temperature of heating before quenching were studied on six nickel-chromium-molybdenum steels (for compositions see table on p. 108). Mechanical properties are plotted, for each of the steels, as a function of temperature of initial heating, for the range 870° to 1480°C. Results are discussed in relation to the individual steels, and from the standpoint of general conclusions which may be drawn from the results as a whole.

The main conclusions are as follows:—

'(1) Where fully martensitic structures were obtained under the experimental conditions employed, an increase in the austenitizing temperature caused a progressive fall in the percentage elongation and reduction of area of the steels investigated, the ultimate tensile strength remaining constant. Results on steel A formed an exception.

'(2) Very high initial heat-treatment temperatures result in brittleness of a different type, due to overheating and burning of the steel. This effect was found to be independent of the structure.

'(3) High initial heating temperatures favour the decomposition of austenite to higher transformation

Table I
Analyses of Steels Used

Steel	C %	Ni %	Cr %	Mo %	Mn %	Si %	S %	P %	N %	O %
A	0·24	4·18	1·30	0·68	0·55	0·27	0·032	0·023	0·011	0·011
B	0·32	3·38	0·65	0·26	0·57	0·22	0·016	0·016	0·010	*
C	0·31	3·40	1·26	0·47	0·44	0·20	0·033	0·036	0·011	0·014
E	0·27	3·80	1·70	0·50	0·36	0·20	0·034	0·036	0·005	0·009
VA	0·33	2·59	0·53	0·58	0·68	0·20	0·039	0·029	0·012	0·009
VB	0·32	2·60	0·51	0·55	0·63	0·22	0·028	0·023	0·009	*

* Not determined.

products than martensite, but complex compositional changes occurring at the elevated temperatures involved may cause an apparent reversal of this tendency.

'(4) A microstructural phenomenon in one of the steels, consisting of a Widsmanstätten pattern of fine dark lines associated with faceted cleavage tensile fractures and a pronounced drop in tensile strength, is shown to result from the preferential precipitation of sulphide inclusions on [100] austenite planes.'

It is suggested that two aspects of the results require further experimental study:

(*a*) The reduction in hardenability which can be produced by high-temperature heating. The authors suggest two alternative mechanisms by which high-temperature heating could favour formation of an intermediate transformation product, rather than of martensite.

(*b*) Precipitation of fine inclusions in steel E after heating above 1350°C., which is believed to be associated with the high solubility of sulphur in this steel, resulting from the low manganese/sulphur ratio.

Surface Hardening of Steel

G. T. COLEGATE: 'The Surface Hardening of Steel. Part III. Pack Carburizing.' *Metal Treatment and Drop Forging*, 1951, vol. 18, Mar., pp. 103-10, 118 (Series to be continued).

For reference to Parts I and II see *Nickel Bulletin*, 1951, vol. 24, No. 4, p. 84.

This instalment discusses the influence of time and temperature of treatment on the depth of case obtainable by pack carburizing: a figure illustrates carbon-concentration gradients for various carburizing times at constant temperature (927°C.), in a steel of the S.A.E. 3115 type (carbon 0·13-0·18, nickel 1·10-1·40, chromium 0·55-0·75, per cent.). A second figure illustrates carbon distribution in the case of a steel carburized at various temperatures, for times sufficient to produce given depths of case.

Defects liable to occur in pack carburizing are discussed, as represented by the two major sources of trouble: (1) spalling or exfoliation of the case, and (2) the presence of soft spots. Causes and methods of prevention of such defects are reviewed.

The characteristics of solid carburizing compounds are dealt with in some detail, with consideration of variations in carburizing power, compositional requirements, selection of type of carburizing compounds for specific types of work, factors retarding carburization, and the use of energizing agents. Later sections contain notes on the handling of the carburizing compounds, re-conditioning and re-activation, and costs. This instalment of the review is supported by a selected *bibliography* of 12 references.

Properties of Low-Alloy Nickel-Chromium-Molybdenum Steels

'Nickel-Chromium-Molybdenum Steels.' *Materials and Methods*, 1951, vol. 33, Mar., p. 105.

Tabular summary of average physical and mechanical properties of steels of the A.I.S.I. 8600 and 8700 series, containing nickel 0·4-0·7, chromium 0·4-0·6, molybdenum 0·15-0·25 or 0·20-0·30, per cent., with carbon 0·18-0·23, 0·28-0·33, 0·38-0·43 or 0·48-0·54, per cent.

Fabricating temperatures, properties, and main uses are also noted. The two series are closely similar in composition, except for molybdenum contents, but the 8700 series are somewhat deeper-hardening, and their properties are maintained in heavier-section sizes than those of the 8600 group.

Extrusion of Nickel-Chromium-Molybdenum Steel Propeller-Blade Blanks

'Squeeze Hot Billets to Make Propeller Blanks.' *Iron Age*, 1951, vol. 167, Mar. 1, p. 125.

This note announces pilot production of hollow steel propeller blanks, by a method developed by Curtiss-Wright Corporation in co-operation with the U.S. Air Force. The extrusion process, involving three steps which occupy only a few minutes, eliminates much tedious hand labour, effects savings in strategic materials, improves the quality of the blading, and increases the strength/weight ratio. Extruded blades are to be produced as quickly as possible, for use in some of the new turbo-prop engines, in which the structure obtained by this method adds high resistance to fatigue and stress. The material used is a nickel-chromium-molybdenum steel. Processes involved on the rough blade, as it comes, in tubular form, from the extrusion press, are briefly enumerated.

It is believed that application of the new method opens up further prospects of saving time and cost in production of other aircraft parts, and of components used in other industries.

Nickel-Chromium-Molybdenum Steel Airscrew Blades

'An Airscrew Development.' *Aeroplane*, 1951, vol. 80, Apr. 13, pp. 441-4.

The article gives an account of the development of the de Havilland hollow steel airscrew, which is based on a type evolved by Hamilton Standard Company in the U.S.A. The advantages of the new design are discussed, and manufacturing and assembly operations are described. The central spar of the de Havilland blades is a high-carbon nickel-chromium-molybdenum steel tubular member, to which is brazed, on the face and camber sides, an outer high-carbon alloy steel sheet aerofoil shell. The three cavities so formed are filled with a low-density reinforced synthetic rubber, to stabilize the shell and to provide a high degree of damping against vibration.

Production of Nickel-Copper-Molybdenum Cast Steel Crankshafts

E. BREMER: 'Casting Steel Crankshafts.'
Foundry, 1951, vol. 79, Mar., pp. 84-7, 245.

A well-illustrated description of methods used by the Auto Specialties Manufacturing Company, St. Joseph, Michigan, in production of cast crankshafts from a steel containing carbon 1·35-1·40, copper 0·50-1·0, manganese 0·70-0·90, silicon 0·85-1·05, nickel 0·45-0·55, molybdenum 0·13-0·18, per cent.

Hubbing Tests on Nickel-Alloy Steels

F. HALWARD: 'Flow Test of Hubbing Steel.'
Metal Progress, 1951, vol. 59, Mar., pp. 356-8.

The nature of the hubbing (or hobbing) process is described, and its increasing importance is urged in connexion with rapid developments in the plastics industries. Properties required in the hub steel and in the die steel are discussed, and a description is given of a flow test developed for assessing the hubability (flow characteristics) of die steels. A 'hubbing index', based on results of such tests, is proposed for steels of the following types: chromium-molybdenum-vanadium (5/0·9/0·25 per cent.), low-nickel-chromium (1·25/0·60 per cent.); 2 per cent. chromium; 5 per cent. chromium-molybdenum; cold-rolled 0·15 per cent. carbon; low-alloy nickel-chromium-molybdenum (0·55/1·35/0·2), low-alloy vanadium, and 4 per cent. nickel nickel-vanadium.

Evaluation Tests for High-Strength Alloy Steels

G. SACHS, G. S. SANGDAHL and W. F. BROWN: 'New Notes on High-Strength Heat-Treated Steels.'
Reprint from Iron Age, Nov. 23 and 30, 1950: see *Nickel Bulletin*, 1951, vol. 24, No. 2, p. 38.
Issued by International Nickel Co., Inc., 1951.

Methods for Rapid Identification of Metals: A.S.T.M. Symposium

See abstract on p. 96.

HEAT- AND CORROSION-RESISTING ALLOYS

The Sigma Phase: A.S.T.M. Symposium

AMER. SOC. TESTING MATERIALS: 'Symposium on the Nature, Occurrence and Effects of Sigma Phase.' *A.S.T.M. Special Tech. Publn.* 110; published 1951; 181 pp.
Containing papers and discussions presented at the Annual Meetings of the Society, June, 1950.

Papers available in preprint form were abstracted in the *Nickel Bulletin* in 1950: to these or other forms of the papers published at an earlier date reference is given below. In the case of papers now published for the first time the scope of the material contained is outlined. In all cases the discussion now reported is additional to material previously available.

F. B. FOLEY: 'Introduction to the Symposium,' pp. 1-2.
Emphasizing the importance of an understanding of sigma-phase formation and effect, in relation to high-temperature metallurgy, and giving a brief outline of the scope of the papers to be presented, with note on some of the principal observations made by the authors.

E. J. DULIS and G. W. SMITH: 'Identification and Mode of Formation and Re-Solution of Sigma Phase in Austenitic Chromium-Nickel Steels,' pp. 3-29; disc., pp. 30-7.
(*Nickel Bulletin*, 1950, vol. 23, Nos. 8-9, pp. 158-9.)

V. T. MALCOLM and S. LOW: 'Sigma Phase in Several Cast Austenitic Steels,' pp. 38-44; disc., pp. 45-7.
(*Nickel Bulletin*, 1950, vol. 23, Nos. 8-9, p. 159.)

P. DUWEZ and S. R. BAEN: 'X-ray Study of the Sigma Phase in Various Alloy Systems,' pp. 48-54; disc., pp. 55-60.
(*Nickel Bulletin*, 1950, vol. 23, Nos. 8-9, p. 158.)

J. W. PUTMAN, N. J. GRANT and D. S. BLOOM: 'Sigma Phase in Chromium-Molybdenum Alloys with Iron or Nickel,' pp. 61-8; disc., pp. 69-70.
The extent of sigma-phase formation in chromium-molybdenum-iron alloys was determined, and some of the properties of the sigma constituent occurring in that system were studied. Molybdenum appears to increase the high-temperature stability of sigma in iron-chromium alloys; in the 60-25-15 chromium-molybdenum-iron alloy it is stable at 1100°C. In this alloy the temperature effect is such that at lower temperatures the tendency for formation of sigma is increased, provided that sufficient time be allowed for the transformation to take place.
A brief section at the end of the paper reports that sigma phase has been found to occur in the central portion of the chromium-molybdenum-nickel system. In view of the fact that sigma had not previously been reported in the chromium-nickel, molybdenum-nickel or chromium-molybdenum systems, the authors consider that the observation which they now report is susceptible to explanation by presuming that either

the sigma in this system represents a ternary compound, or that present knowledge of the constituent binary systems is inadequate. (In connexion with the chromium-nickel alloys, see note by SULLY et al., abstracted in *Nickel Bulletin*, 1951, vol. 24, No. 4, p. 76.)

In discussion, P. A. BECK stated that research in progress at the University of Notre Dame confirms the authors' conclusion that a ternary phase similar to other known sigma phases occurs in the chromium-nickel-molybdenum system.

L. MENEZES, J. K. ROROS and T. A. READ: 'The Tetragonality of the Sigma Phase in the Iron-Chromium System,' pp. 71-4; disc., p. 74.

Study of single-crystal specimens of 50-50 iron-chromium sigma phase, prepared by isothermal transformation of coarse-grained ferrite of this composition at 775°C.

J. J. HEGER: 'The Formation of Sigma Phase in 17 per cent. Chromium Steel,' pp. 75-8; disc. pp. 79-81.

By application of cold work and the use of extended heating periods at 900°, 1050° and 1200°F. (482°, 540° and 648°C.), it was found possible to form sigma in 17 per cent. chromium (Type 430) steel. At 900°F. the phase was precipitated as particles too finely dispersed to be identified; at 1050°F. the phase formed as larger particles and was positively identified as sigma; at 1200°F. but little of the phase formed.

In discussion, the author stated that to date it had not been found possible to produce sigma in 12 per cent. chromium steels, even after heating as long as 10,000 hours at 900°F.

G. N. EMMANUEL: 'Sigma Phase and Other Effects of Prolonged Heating at Elevated Temperatures on 25 per cent. Chromium-20 per cent. Nickel Steel,' pp. 82-99; disc., jointly with Jackson's paper (*vide infra*), pp. 120-7.

(*Nickel Bulletin*, 1950, vol. 23, Nos. 8-9, pp. 160-1.)

J. H. JACKSON: 'The Occurrence of the Sigma Phase and its Effect on Certain Properties of Cast Fe-Ni-Cr Alloys,' pp. 100-19; disc., jointly with Emmanuel's paper (*vide supra*), pp. 120-7.

This paper deals with the occurrence of sigma in two of the most popular types of cast heat-resisting alloy, the 26-12 and 26-20 chromium-nickel types, designated, respectively, by the Alloy Casting Institute, the HH and HK grades. The importance of balanced composition is urged and particular attention is given to the detrimental influence of sigma on the thermal-shock resistance of high-temperature casting materials of these types. A thermal-shock test devised at the Battelle Memorial Institute is described, and data are presented on the thermal-fatigue resistance of the 26-12, 15-35, 12-60, 17-66, and 28-9 chromium-nickel types of cast alloy. The behaviour of these alloys was studied on specimens having compositions adjusted to produce structures consisting of (1) austenite+carbides, (2) austenite, a moderate amount of sigma, and carbides, and (3) austenite, a large amount of sigma, and carbides. The results indicate conclusively that optimum resistance to thermal fatigue can be developed only in alloys which do not contain appreciable amounts of sigma phase.

A detailed report is also made of an investigation of the susceptibility to sigma formation of the 26-20 chromium-nickel alloy, as influenced by minor modifications of composition and treatment. The data reported are interpreted as showing that optimum properties are produced in this material by keeping the chromium and silicon contents relatively low, and the carbon reasonably high. Such recommendations must be acted upon with discretion, since unduly low chromium impairs resistance to oxidation and corrosion, silicon contents must not be too low, in the interests of resistance to carburization, and an excessively high carbon content may engender brittleness from presence of carbides.

The following classification is made of (1) sigma-free and (2) sigma-bearing alloys of the chromium-nickel-iron group:—

'*Sigma-Free Alloys*

The following heat-resisting alloys are believed to be not susceptible to sigma formation.

HF (20 per cent. chromium, 10 per cent. nickel), HT (15 per cent. chromium, 35 per cent. nickel), HU (19 per cent chromium, 39 per cent. nickel), HW (12 per cent. chromium, 60 per cent. nickel), and HX (17 per cent. chromium, 66 per cent. nickel).

'*Sigma-Bearing Alloys*

The sigma phase is commonly found in heat-resistant alloys of the HC (28 per cent. chromium, 4 per cent. max. nickel), HD (28 per cent. chromium, 5 per cent. nickel), HE (28 per cent. chromium, 9 per cent. nickel), and HL (30 per cent. chromium, 20 per cent. nickel) types. These alloys are not likely to be used in service where stresses are severe, hence their utility is not limited by any detrimental effect of the sigma phase.'

R. S. STEWART and S. F. URBAN: 'The Formation of Sigma and its Influence on the Behaviour of Stabilized 18 per cent. Chromium-8 per cent. Nickel Steels in Concentrated Nitric Acid,' pp. 128-45.

(*Nickel Bulletin*, 1950, vol. 23, No. 12, p. 234: from *Iron Age*.)

W. O. BINDER: 'Some Notes on the Structure and Impact Resistance of Columbium-bearing 18-8 Steels after Exposure to Elevated Temperatures,' pp. 146-64; disc., p. 164.

(*Nickel Bulletin*, 1950, vol. 23, Nos. 8-9, p. 160.)

F. W. SCHMITZ and M. A. SCHEIL: 'Observations of the Effect of Sigma on the Mechanical Properties of Columbium-Stabilized Weldments in Austenitic Stainless Steels,' pp. 165-77; disc., pp. 178-81.

In recent years there has been an increasing demand for thick-walled pressure vessels in chemical plant, in which in some cases operating temperatures are above 600°F. (315°C.). In order to ensure freedom from carbide precipitation, niobium-stabilized steel is specified for these vessels, and the manufacturing codes for pressure vessels have laid down stress-relief treatments after welding. Since some of the temperatures specified

for these treatments are within the range in which sigma formation is known to occur, an extensive study was made of their effects on structure and mechanical properties of the welds, using Type 347 (niobium-stabilized steel). The results are reported in this paper.

Conclusions with reference to the ductility of all-weld-metal tension-test bars are given below:—

'(1) Maximum ductility of 30 per cent. and over is obtained in the 'as-welded' condition with ferrite contents between 3 and 8 per cent. when no sigma is present.

'(2) Ductility varying between about 10 and 30 per cent. is obtained after heat treatments producing sigma contents from 5 to 1 per cent.

'(3) Weld metal with ferrite in the as-deposited condition does not always sigmatize to the full extent possible.

'(4) Size and distribution of the sigma phase affects the ductility. Larger particles of sigma, in a segregated pattern, are more effective in lowering ductility than smaller particles.

'(5) Variations of welding technique, such as thick and thin weld layers, and peening, affect ductility only in so far as they influence the amount of sigma produced on heat treatment.'

Etching of Steels for Identification of Sigma Phase

J. J. GILMAN: 'Etching Steels which contain the Sigma Phase.' *Metal Progress*, 1951, vol. 59, Mar., pp. 377, 376B.

During an investigation of etching reagents suitable for detection of sigma phase in high-alloy chromium-nickel-iron alloys it was observed that the modes of attack of the respective solutions varied considerably. This article presents a series of photomicrographs demonstrating the delineation obtainable by some of the most promising etchants. Strict comparison is made possible by showing the same field of a specimen of Type 314 stainless steel (25-20 containing silicon), which had been heated for 1670 hours at 1500°F. (815°C.), resulting in formation of sigma phase along the grain boundaries and of a Widmanstätten pattern within the grains. Etchants used, and effects obtained, are noted below:—

(1) *Vilella's hydrochloric-picric acid reagent*: dissolves the austenitic matrix rather more rapidly than it dissolves either the carbides or the sigma phase. The latter constituents stand out in relief against the background.

(2) *Oxalic acid, used electrolytically*: opposite form of attack; sigma and the carbides attacked before the matrix; carbides and sigma show grey, outlined in black.

(3) *Aqueous solution of lead acetate, used electrolytically*: stains the surface with a thin film (possibly ferric acetate), which forms most rapidly on the austenite of the matrix, less rapidly on the sigma phase, and least rapidly on the carbides. As the thickness of the film increases the colour changes, e.g., at time of exposure the colours of austenite, sigma and carbides were, respectively, light blue, dark blue and tan. Time of etching affects the colours produced.

(4) *Cadmium acetate, used electrolytically*: stains carbides more rapidly than the sigma phase.

(5) *Sodium hydroxide, used electrolytically*: stains the sigma phase before the carbides or matrix.

It is urged that a further search for selective etchants is desirable.

Nickel-containing Spring Materials

See abstract on p. 103.

Fatigue Strength of Welded Austenitic Nickel-Chromium Steel

I. WEIBULL and P. DAVIDSON: 'The Fatigue Strength of Welded 18-8 Steel at High Temperature.' *Jernkontorets Annaler*, 1950, vol. 134, Dec., pp. 559-71.

'Fatigue strength of welded 18-8 steel sheet was investigated at a temperature of 650°C. Four different grades were studied, two stabilized with titanium, and one with niobium, while the fourth was of very low carbon content and was unstabilized.

'The best results were obtained with a titanium-stabilized steel, which was free from grain-boundary carbide and showed a very low content of delta ferrite in the weld and in the heat-affected zone.'

Immersion-Corrosion Tests by Panama Canal Authorities

H. W. MUNDT, L. J. THOMPSON and S. J. STACY: 'Report of Metals Corrosion Investigation, Immersion Tests; Five Years' Duration, Initiated 1941.' (Summary and conclusions only.)
Corrosion, 1951, vol. 7, Feb., p. 51.

The tests covered by this report, completed in 1946, were conducted with the specific object of obtaining urgently needed information on the corrosion-resistance of materials to be used by the Panama Canal authorities for maintenance of existing facilities and for additional construction projected in the near future.

Exposure was in Isthmian fresh, brackish and sea waters, for one-, three-, and five-year periods. Welded and bare uncoupled ferrous and non-ferrous materials were tested; full details are given in the report, but not in the summary.

Within the limits of the investigation, the following conclusions are drawn:—

'(*a*) Exclusive of the welds, stainless steels, and zinc, the rates of corrosion in i.p.y. are rather uniform and fall within relatively narrow range bands, as based on the five-year exposure results for each of the ferrous and non-ferrous groups if considered separately.

'(*b*) The rates of corrosion of the different grades of uncoupled zinc do not differ significantly if the results for the five-year exposures and all environments are considered.

'(*c*) Considering the results as a whole, the continuous brackish-water environment is the most aggressive of these tested.

'(*d*) As indicated by the five-year exposures and considered as a group, excluding zinc, the non-ferrous metals show better resistance to corrosion in sea water than in fresh water, and least resistance in brackish water.

'(*e*) The welded sections of the majority of welded specimens exposed in sea water at mean tide were in good condition after exposure, except copper-nickel structural and copper-bearing steels and nickel.'

A table shows spread and average i.p.y. values for the one-year and five-year exposures for the ferrous materials (low-alloy steels and wrought iron).

Factors affecting Behaviour of Stainless Steels in Acid Solutions

J. M. DEFRANOUX: 'Reasons for Variation in the Behaviour of Stainless Steels in Certain Acid Solutions and Means for Overcoming Them.'
Rev. du Nickel, 1951, vol. 17, Jan.-Mar., pp. 4-9.

Report of investigation of the behaviour of 18-8-Mo steel in sulphuric-acid solutions, by means of time/potential studies correlated with loss-in-weight values after 48-hour exposure periods. The solutions were prepared from chemically pure acid and distilled water, and the influence of impurities was determined by investigation of the behaviour of the steel in acid solutions containing controlled amounts of organic and inorganic substances. The effect of surface condition of the steel was also investigated.

The results indicate that both purity of the solution and surface condition of the material play an important part in determining resistance to corrosion. A small addition of an oxidizing 'corrective' to the acid solution, and preliminary passivating treatment of the steel, considerably extend the useful range of application of the 18-8-Mo steel in handling sulphuric acid. It is shown that such oxidizing additions function in a manner totally different from that operative in the case of 'inhibitor' additions.

On the basis of the observations made, the author recommends that, prior to exposure to sulphuric acid solutions, stainless steel should be left, for about 48 hours, exposed to the atmosphere, or that it should be subjected to a special passivating treatment.

It is emphasized that in media in which passivity is established only gradually, or after the lapse of a certain time of exposure, resistance to corrosion can be correctly assessed only on the basis of a series of tests planned to evaluate the influence of all the variables involved.

Resistance of Nickel-containing Materials to Chromic Acid

'Chromic Acid vs. Materials of Construction.'
Chemical Engineering, 1951, vol. 58, Feb., pp. 147, 243-4, 246-8; Mar., pp. 220-2.

This article, comprising short notes on the materials shown below, supplements information given in the Materials of Construction report published in the November, 1950, issue of this journal. Materials covered: high-silicon irons, coatings, iron and steel, stainless steel, glass, rubber, tantalum, nickel and nickel alloys, carbon, lead, chemical stoneware, Durimet 20, Chlorimet alloys, aluminium, wood, cements, silicones, Worthite, porcelain, Hastelloy alloys.

Comments on nickel-containing materials are given below:—

Stainless Steels. Straight chromic-acid solutions of high concentration attack these steels, but with other chemical compounds in solution, or with chromic acid alone in low concentrations, at moderate temperatures, austenitic nickel-chromium steels are used with good results. Mixtures of chromic acid with other acids may be critical. Chromium-plating baths are safely handled at temperatures of the order of 70°F. (21°C.) in Type 304 stainless-steel tanks, but service at higher temperatures depends closely on concentrations and temperatures. At room temperature the stainless steels are satisfactorily resistant to dilute chromic-acid solutions, but appreciable attack begins at 170°-180°F. (76°-83°C.) and at boiling Type 316 is the only grade suitable for handling solutions containing over 10 per cent. acid.

Nickel and Nickel Alloys. Nickel, Monel and Inconel are usefully resistant to dilute chromic-acid solutions at room temperatures, but are considerably attacked at higher temperatures. In addition, nickel and Monel may, under some conditions, be subject to intergranular attack by hot solutions, resulting in embrittlement. Most of the applications of these materials are for fixtures and racks handling work through chromic-acid plating and cleaning solutions.

Durimet 20. Resistance of this material to chromic-acid solutions varies and its limit of applicability is not yet accurately known. The indications appear to be that for dilute solutions at normal temperatures it can be used satisfactorily, but that it is susceptible to sharp attack at higher temperatures and concentrations.

Chlorimet Alloys. Due to the oxidizing character of chromic acid, Chlorimet 2 is not recommended, but Chlorimet 3 (nickel-base, containing 18 per cent. each of molybdenum and chromium) shows excellent resistance. It is, however, not widely used in this connexion, due partly to the good resistance and lower cost of Duriron, and partly because Chlorimet 3 is produced only in cast form.

Worthite. Worthite pumps are successfully used in handling chromic acid for anodizing aluminium, and chromium-plating solutions. It has also been found suitable for contact with the chrome tanning solutions employed in the leather industry: typical corrosion-test data are quoted.

Hastelloy. For economic reasons, use of Hastelloy for handling chromic-acid solutions has been somewhat limited. Alloys B and D are not resistant to this acid, but C shows good resistance, and has been used to a limited extent in pumps and valves of plating baths. There has also been some application of the alloy in the tanning industry. Laboratory tests indicate that attack is much intensified by rise in temperature of the acid.

Resistance of Nickel-containing Materials to Citric Acid

'Materials of Construction vs. Citric Acid.'
Chemical Engineering, 1951, vol. 58, Mar., pp. 211-12, 214, 216, 218-20.

The behaviour of the following materials in contact with citric acid is reviewed: Worthite, coatings,

cements, wood, glass-lined steel, lead, rubber, porcelain, silicones, tantalum, iron and steel, Durimet 20, Chlorimet alloys, high-silicon irons, aluminium, stainless steel, nickel and high-nickel alloys, carbon, stoneware.

Worthite gives specially good resistance to citric-acid products, and finds extensive use in plant handling citrus-fruit juices, and in pharmaceutical equipment processing citric acid and citrates.

Durimet 20 shows good resistance, even at high concentrations and at raised temperature. It is also recommended for handling citric acid in combination with sulphuric acid.

Chlorimet Alloys are satisfactorily resistant to citric-acid solutions at all concentrations and temperatures up to boiling. They are, however, little used in this connexion, due to the availability of other less expensive alloys which show adequate resistance.

Stainless Steels are generally well suited for most equipment handling citric acid as used in the food-processing, pharmaceutical and related industries. When concentrated solutions at or near boiling point are involved, Type 316 (molybdenum-containing) grade should be used.

Nickel and Nickel Alloys. Monel, nickel and Inconel are usefully resistant to unaerated citric-acid solutions of all concentrations, at temperatures up to and including boiling. Rates of corrosion are increased by aeration, especially at elevated temperatures. Monel is generally more resistant to boiling concentrated solutions than nickel or Inconel, but under highly aerated conditions Inconel has the maximum corrosion resistance. Both alloys find extensive use in the handling of citrus-fruit juices.

Ni-Resist has good resistance to dilute unaerated solutions at moderate temperatures.

Stainless-Steel Liquid-Nitrogen Storage Tanks

J. A. TOLAND: 'Welded Spheres Solve Liquid Nitrogen Storage.' *Iron Age*, 1951, vol. 167, Mar. 29, pp. 86-8.

In connexion with tests on supersonic aircraft a problem was presented by the requirement for supply of gaseous nitrogen at extremely high pressure (6500 p.s.i.), in large volume; this could not be met by commercial service. The problem was solved, at the Edwards Air Force Base, by developments jointly sponsored by Linde Air Products Company and Research Welding Engineering Company, which are described in this article.

Liquid nitrogen is fed by gravity-feed system, from permanent-base equipment, to a 200-gal. pressure sphere, and is forced, under pressure, from the container into an evaporator or heat exchanger. Gaseous nitrogen is produced, at any desired pressure up to about 10,000 p.s.i., by controlling the boil-off rate of the liquid.

The article describes design and fabrication methods developed for the storage tanks, which are required to meet a specification of 15 ft.-lb. Charpy impact at −300°F. (−184°C.). Steel to A.S.T.M. A-240 proved suitable for this application, and design criteria were formulated in accordance with A.S.M.E. Boiler Code paragraph U-200 for unfired pressure vessels. The steel is a modified Type 347, of the following composition: carbon 0·08 max., silicon 0·85 max., manganese 2·50 max., phosphorus 0·035 max., sulphur 0·030 max., chromium 17·00 min., nickel 9·50 min., per cent., with a niobium content not less than 10 times that of the carbon, with maximum at 1 per cent. Methods used for powder cutting of the plate, heat-treatment and rapid quenching, and inspection procedure are described.

Lining of Sulphate Digesters

T. T. COLLINS, S. J. BAISCH and G. T. VAN DER VELDEN: 'Corrosion and Field Lining of Sulphate Digesters.' *Paper Trade Jnl.*, 1951, vol. 132, Feb. 9, pp. 24, 26-7; Feb. 16, pp. 18-26 (even numbers).

Part of a series of articles based on experience and practice at the plant of Thilmany Pulp and Paper Company and other large installations in the industry.

Introductory notes on the intensification of corrosion problems in sulphate digesters which have occurred during recent years are followed by an account of methods adopted to minimize attack. These include use of inhibitors, modification of thermal and other operating conditions, and the use of linings of ceramic or of corrosion-resisting metallic materials. Lining methods used, and the materials selected for the linings, are discussed at some length, with informative illustrations, and the writer's experience is supported by references to the literature of lined materials in chemical plant. Stainless steels of austenitic grades, Inconel, and Monel, have all proved useful in this type of service; their respective applications are described. These articles and the earlier ones in the series are supported by a *bibliography* of 62 references.

Stainless-Steel Screens in Coal Mines

C. G. PURNELL: 'How Stainless Steel Improves Screening Results.' *Coal Age*, 1949, vol. 54, Nov., pp. 88-90.

Test data accumulated over a period of years have definitely established the superiority of stainless steels for screens in various types of coal-handling service. The advantages of stainless for this purpose include resistance to erosion, wear-resistance (ensuring maintenance of correct sizing by the perforated units), corrosion-resistance (minimizing 'blinding'), strength and toughness (making possible the use of thinner and lighter screens). Reduction of shut-down time is reduced to a minimum and efficiency of operation is much increased. Type 410 (high-chromium) is very largely used, and where extremely corrosive conditions are encountered 18-8 chromium-nickel steel is preferred.

Typical service records reported in this article include the use of 18-8 screens handling anthracite under acid conditions (replacing silicon bronze); Types 410 and 18-8 in refuse-shakers and in de-watering and sizing screens in bituminous mining; Type 410 in cleaning systems using calcium chloride, and stainless-steel screens for air-cleaning tables, replacing bronze. In all the cases quoted, introduction of steel screens has effected improvement in operation, and lengthened life, combined, in many cases, with reduction in working costs.

Hot Working, Heat Treatment, Welding and Finishing of High-Alloy Steels

J. A. MCWILLIAM: 'Manipulation of Corrosion- and Heat-Resisting Steels.'
Welding and Metal Fabrication, 1951, vol. 19, Apr., pp. 133-9.

The article is a sequel to that published, *ibid.*, Jan., pp. 19-24; see *Nickel Bulletin*, 1951, vol. 24, No. 3, p. 60. It deals, from an essentially practical standpoint, with hot forging, and drop stamping, hot dishing and flanging, and heat treatment, of high-chromium and -nickel-chromium steels. Factors requiring consideration on account of the inherent characteristics of these steels are discussed, and recommendations are made for processing of the various grades.

In connexion with welding of 18-8 chromium-nickel steel, particular consideration is given to the use of jigs; procedure for welding of stainless-steel drums, and the halves of nozzle bends for aircraft engines are specifically discussed. The final section is a condensed summary of procedure for de-scaling and for grinding and polishing.

Grinding and Polishing of Stainless Steel

A. E. BROWN: 'Coated Abrasives in the Grinding and Polishing of Stainless Steel. Part A. Prior to Fabrication.' *Electroplating*, 1951, vol. 4, Mar., pp. 77-80.

Commercial mill finishes in which stainless steel (18-8 and related types) is supplied are listed, and a description is given of machines used for production of the various finishes on steel in (1) sheet, bar or strip form, and (2) cylinder or tube form.

Under (1) two types of machine are considered and under (2) external grinding (by the backstand, or by the duplex-belt method), and internal grinding, are discussed. In all cases types of abrasive used and mode of operation of the machines are described.

Spinning of Nickel-containing Materials

See abstract on p. 103.

Arc Welding of Nickel-Clad and Stainless-Clad Steel

See abstract on p. 98.

Welding of Nickel and High-Nickel Alloys

See abstract on p. 106.

Extra-Low-Carbon Austenitic Welding Electrodes

R. K. LEE: 'Stainless Arc Welded without Columbium.' *Steel*, 1951, vol. 128, Mar. 19, pp. 71-2.

Effects produced in the heat-affected zone of welded austenitic steels, and the rôle of carbon in causing susceptibility to intergranular corrosion are discussed as a preliminary to arguments in support of the use of E.L.C. electrodes (carbon 0·03 per cent. max.). Examples of welds made with such electrodes are shown, to demonstrate the possibility of conserving niobium by obviating the need for using alloy additions to secure stabilization.

'Flux-Injection' Flame-cutting of Stainless Steel

G. E. BELLEW: 'New Developments in Flame Cutting Stainless Steel.' *Welding Jnl.*, 1951, vol. 30, Mar., pp. 265-8.

The flux-injection method, introduced some years ago by Air Reduction Sales Company, solved, to some extent, problems associated with flame-cutting of stainless steel, making it possible to produce cuts of satisfactory quality, at reasonable cost, in many grades. It was not, however, possible, by the original process, to handle risers of any considerable thickness, and steel of the 25-20 types.

This paper, relating to recent developments, describes the use of a more efficient fluxing agent, which extends the applicability of the process to thicker sections, and to materials of higher alloy composition, e.g., 25-220 and 35-15 grades. Technique of the improved process is discussed and potential performance is exemplified by reference to typical production cutting experience.

Methods for Rapid Identification of Metals: A.S.T.M. Symposium

See abstract on p. 96.

Electroplating of Stainless Steel

See abstract on p. 101.

Attention is drawn to the fact that many of the names of materials mentioned in The Nickel Bulletin are *Registered Trade Marks*.

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